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RESEARCH MEMORANDUM

PRELIMINARY INVESTIGATION OF AN ANNULAR TURBOJET
COMBUSTOR HAVING A CATALYTIC-COATED LINER

By Carl T. Norgren and J. Howard Childs

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

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WASHINGTON
January 27, 1954

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HAVING A CATALYTIC-COATED LINER

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SUMMARY

The performance of an experimental annular turbojet combustor was investigated at a low-pressure operating condition with an uncoated liner, with an identical liner having a ceramic coating on the inner walls, and with this same liner having a catalytic coating added onto the ceramic coating. The combustion efficiency was approximately the same for all three liners, thus indicating no gain in performance through the use of the catalytic coating.

INTRODUCTION

The operation of current turbojet engines at high altitudes is limited to a great extent by combustor performance deficiencies such as low combustion efficiency and flame blow-out. The NACA Lewis laboratory is engaged in research directed toward an understanding of design criteria that will alleviate these performance deficiencies. As part of this research, the investigation reported herein was conducted to determine the effect of a catalytic-coated combustor liner on the altitude performance of an experimental turbojet combustor.

One of the principal design variables affecting the altitude performance of turbojet combustors is the size of the combustion space. Values of combustion efficiency obtained at operating conditions of equal severity with 14 different turbojet combustors are compared in reference 1; this comparison shows a trend of higher combustion efficiency with larger combustors. Additional unpublished data show that the combustion efficiency of geometrically similar combustors of different diameters follows a similar trend. Since the volume-to-surface ratio of the combustion space is an approximate index of the relative performance obtained with different combustors, as discussed in reference 1, the data indicate that the walls of the combustor liner exert a deleterious effect on the combustion process. It has been suggested that the effect of the liner walls on the turbojet combustion process may be

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analogous to the effect of wall quenching observed in small-scale combustion apparatus. Various investigators have measured the quenching distance, that is, the distance over which a metal wall exerts a quenching effect on a flame (e.g., ref. 2).

Platinum is one of the materials that are known (ref. 3) to accelerate rather than quench the oxidation of hydrocarbon fuels. If a strip of platinum or platinum-coated metal is placed in a jet of premixed propane and air, the mixture will be ignited at room temperature. This occurs because platinum serves as a contact catalyst for the oxidation of hydrocarbon fuels and increases the speed of the chemical reaction to the point where flame occurs even though no high-temperature ignition source is present.

These considerations led to the investigation of a turbojet combustor having a liner with the inner walls coated with a commercial material containing platinum and known to have a catalytic effect on the combustion of hydrocarbon fuels. The investigation was conducted in a one-quarter segment of a 25.5-inch-diameter annular turbojet combustor installed in a direct-connect duct. The combustor was similar to the best configuration reported in reference 4. The combustor was investigated at conditions simulating flight at 85 percent rated rotor speed, 80,000-foot altitude, and flight Mach number of 0.6 in a turbojet engine having a compressor pressure ratio of 5.2:1. At these simulated flight conditions, the combustion efficiency was substantially below 100 percent; so any benefits derived from the catalytic coating could be readily observed. The combustor was investigated with an uncoated liner, with an identical liner having a ceramic coating on the inner walls, and with this same liner having a catalytic coating added onto the ceramic coating. Data showing combustion efficiency obtained with each of these combustor liners are included herein.

APPARATUS

Installation

The combustor installation is shown in figure 1 and was similar to that of reference 4. The combustor-inlet and combustor-outlet ducts were connected to the laboratory air supply and low-pressure exhaust systems, respectively. Air-flow rates and combustor pressures were regulated by remote-controlled valves located upstream and downstream of the combustor. The desired combustor-inlet temperature was obtained by means of an electric air heater.

Instrumentation

Air flow was metered by a concentric-hole, sharp-edge orifice installed according to A.S.M.E. specifications. The fuel used in this investigation was vaporized commercial propane supplied from the laboratory distribution system. The vapor fuel-flow rate was metered by a calibrated sharp-edge orifice. Thermocouples and pressure tubes were located at the combustor-inlet and combustor-outlet stations indicated in figure 1. The number, type, and position of these instruments are indicated in figure 2. The combustor-outlet thermocouples and total-pressure rakes were located at centers of equal areas in the duct. Pressure tubes were connected to manometers; thermocouples were connected to a self-balancing recording potentiometer.

Combustor

The combustor consisted of a one-quarter segment (90°) of a single annular combustor having an outside diameter of 25.5 inches, an inside diameter of 10.6 inches, and a length from fuel injectors to combustor-outlet thermocouples (station 2) of approximately 25 inches. The maximum combustor cross-sectional area was 105 square inches (corresponding to 420 sq in. for the complete combustor). A longitudinal cross-sectional view of the combustor is shown in figure 3, and a cutaway view is shown in figure 4. The vaporized propane was injected into the combustor to simulate the performance that would be obtained by using liquid jet fuel with a prevaporizer built into the combustor. Five equally spaced $7/64$ -inch orifices (corresponding to 20 orifices in the complete combustor) injected the propane fuel. Additional fuel injectors were located between these vapor injectors for the purpose of supplying liquid fuel to obtain the higher fuel-flow rates required for low-altitude operation; fuel-flow rates requiring use of the liquid injectors were not investigated, however.

Details of the combustor liner are shown in figure 5. The combustor was similar to the best configuration developed in reference 4 (model 28I). This combustor differed from model 28I in two important respects, however. The combustor liner was prepared from another experimental combustor which had previously been investigated. It was necessary to weld patches over several large holes in the upstream end of this combustor liner, as indicated by the cross-hatched areas in figure 5. Because all the patches did not completely fill the holes, tiny cracks were left between the edge of the patches and the edge of the holes, which allowed additional air to be admitted into the primary combustion zone. The second way in which the combustor used in this investigation differed from model 28I was the provision made for disassembling the combustor liner into an upstream portion and a downstream portion. The liner could be taken apart along a seam located approximately 8 inches

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from the upstream end of the liner as indicated in figures 3 to 5. The two pieces of the liner were held together along this seam by means of overlapping metal tabs and sheet-metal screws. Some leakage of air occurred along the seam, thereby providing a slightly different air flow in the combustion space than that intended for the model 28I design.

For part of the investigation the combustor had a ceramic coating on the inner walls of the upstream portion of the combustor liner. The ceramic coating was a mixture of Sauereisen No. 1 and a high-temperature protective coating (Saverite 4000). During another phase of the investigation, a catalytic coating was added onto this ceramic coating. The catalytic coating was applied to the surface of the ceramic by Oxy-Catalyst Manufacturing Co., Inc., of Wayne, Pennsylvania. Although the exact composition of the catalyst is not available, it is known to contain platinum and to exert a catalytic effect on the oxidation of hydrocarbon fuels.

PROCEDURE

The different combustor liners were investigated at a single test condition: combustor-inlet pressure, 5 inches mercury absolute; combustor-inlet total temperature, 268° F; air flow per unit combustor reference area, 0.714 pound per second per square foot. These conditions simulate operation of the combustor in a turbojet engine having a 5.2 compressor pressure ratio and operating at a Mach number of 0.6, an altitude of 80,000 feet, and a rotor speed of 85 percent.

Combustion efficiency was computed by the method of reference 5 as the percentage ratio of actual to theoretical increase in enthalpy from the combustor-inlet to the combustor-outlet instrumentation plane (stations 1 to 2). The arithmetic mean of the 30 outlet thermocouple indications was used to obtain the value of combustor-outlet enthalpy.

RESULTS AND DISCUSSION

In figure 6 is presented a comparison of the combustion efficiencies obtained with the uncoated liner, with the ceramic-coated liner, and with the catalytic-coated liner. All the data points fall within ± 2 percent of a single curve. There is no indication of any gain in combustion efficiency resulting from the use of the catalytic coating on the inner walls of the combustor liner. Before the data shown in figure 6 for the catalytic-coated combustor liner were recorded, the combustor was operated for approximately 5 hours in order to condition the catalyst. As with uncoated liners of similar design, there was no indication of incandescence at the walls of the catalytic-coated combustor.

These data demonstrate that for the particular catalyst and method of application investigated, there was no beneficial effect on the turbojet combustion process. This investigation was limited in scope, however, and the utilization of other catalytic materials or other techniques for their application might prove worthwhile. Reference 6 shows that the same type ceramic coating on the walls of a tubular turbojet combustor liner resulted in higher combustion efficiencies, and this effect was attributed to more rapid evaporation of liquid fuel from the liner walls. In the investigation reported herein, no such effect of the ceramic coating would be anticipated since vapor fuel was used. The data of figure 6, which show the combustion efficiency to be approximately the same for the uncoated liner and for the ceramic-coated liner, are therefore in accord with expectations.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, November 30, 1953

REFERENCES

1. Norgren, Carl T., and Childs, J. Howard: Effect of Liner Air-Entry Holes, Fuel State, and Combustor Size on Performance of an Annular Turbojet Combustor at Low Pressures and High Air-Flow Rates. NACA RM E52J09, 1953.
2. Lewis, Bernard, and von Elbe, Guenther: Combustion, Flames and Explosions of Gases. Academic Press, Inc. (New York), 1951, pp. 303-304; 379-388.
3. Seabright, H.: An Investigation of Catalytic Ignition and Flame Holders. Rep. No. M-46-1, Airplane Div., Curtiss-Wright Corp., Sept. 26, 1946. (Air Materiel Command Contract W 33-038-ac-14161 and Bur. Aero. Contract NOa(s)-8275.)
4. Norgren, Carl T., and Childs, J. Howard: Performance of an Annular Turbojet Combustor Having Reduced Pressure Losses and Using Propane Fuel. NACA RM E53G24, 1953.
5. Turner, L. Richard, and Bogart, Donald: Constant-Pressure Combustion Charts Including Effects of Diluent Addition. NACA Rep. 937, 1949. (Supersedes NACA TN's 1086 and 1655.)
6. Butze, Helmut F., and Jonash, Edmund R.: Turbojet Combustor Efficiency with Ceramic-Coated Liners and with Mechanical Control of Fuel Wash on Walls. NACA RM E52I25, 1952.

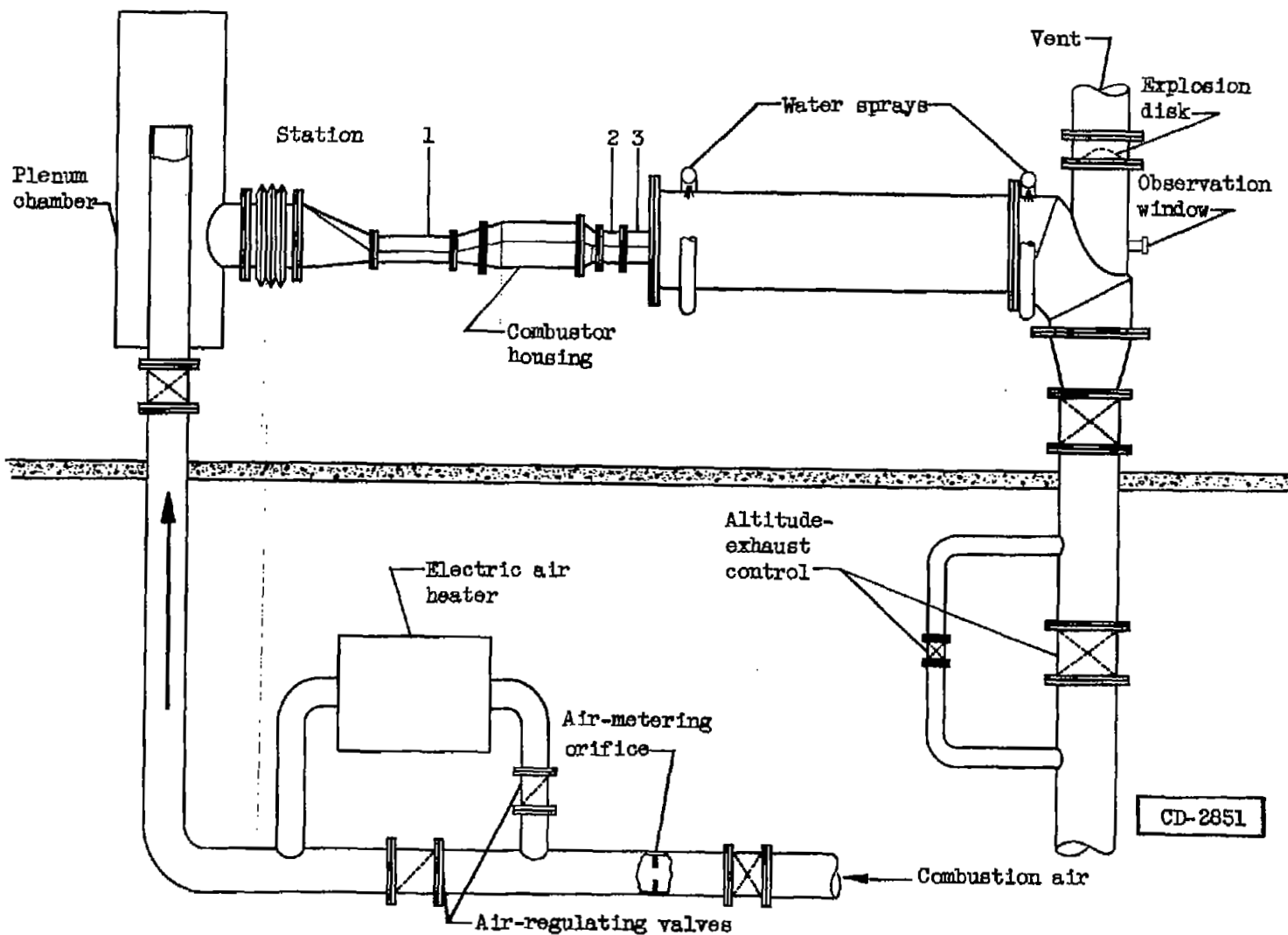
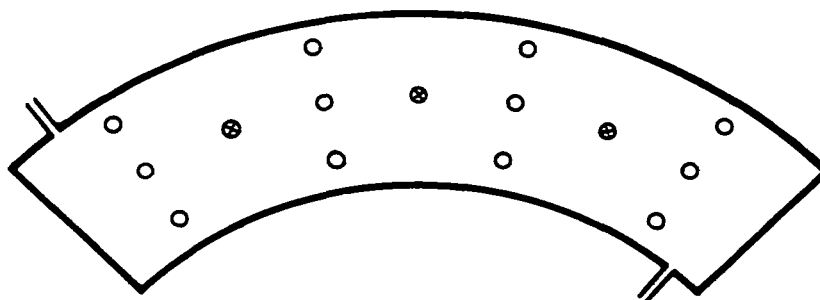


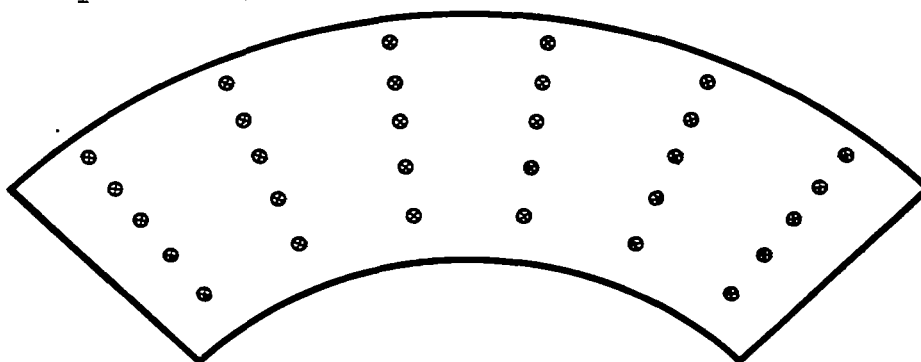
Figure 1. - Installation of one-quarter segment of 25.5-inch-diameter annular combustor.

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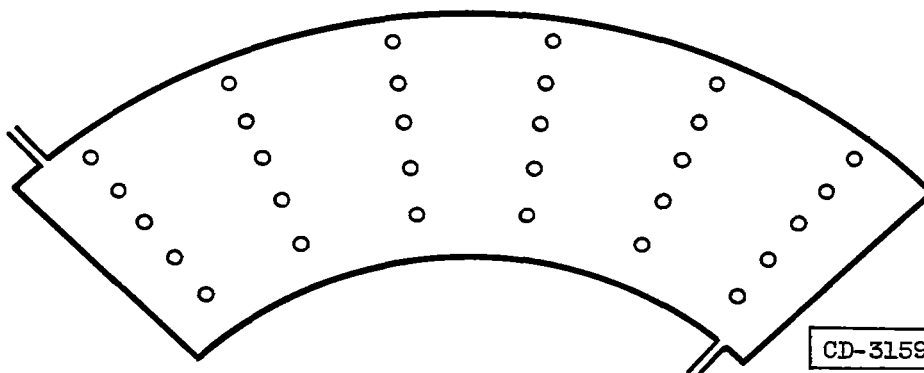


(a) Inlet thermocouples (iron constantan), inlet total-pressure rakes, and stream static probe in plane at station 1.

- ⊗ Thermocouple
- Total-pressure rake
- └└ Static-pressure orifice



(b) Outlet thermocouples (chromel-alumel) in plane at station 2.



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(c) Outlet static- and total-pressure probes in plane at station 3.

Figure 2. - Locations of instrumentation.

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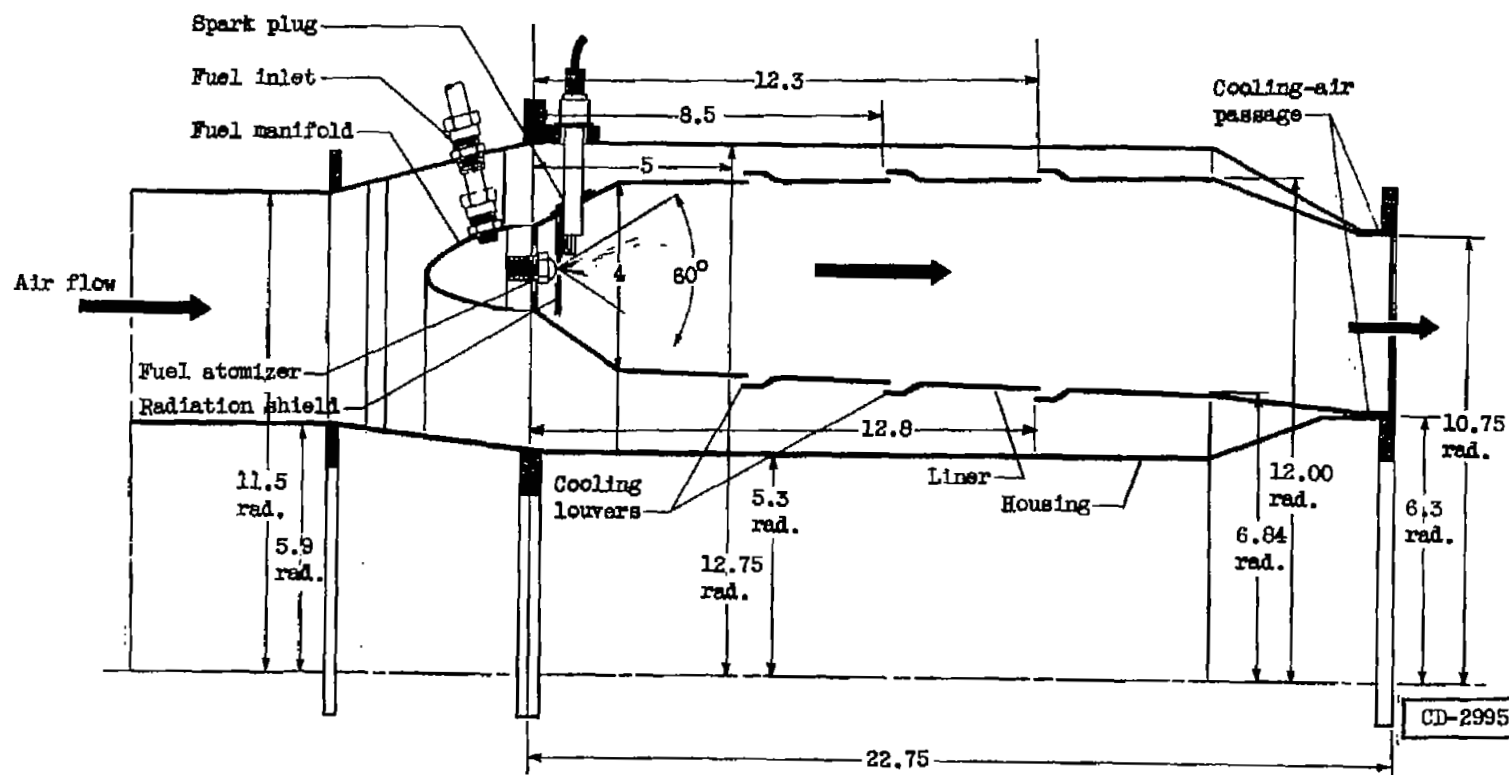


Figure 3. - Longitudinal cross-sectional view of annular combustor. (Dimensions are in inches.)

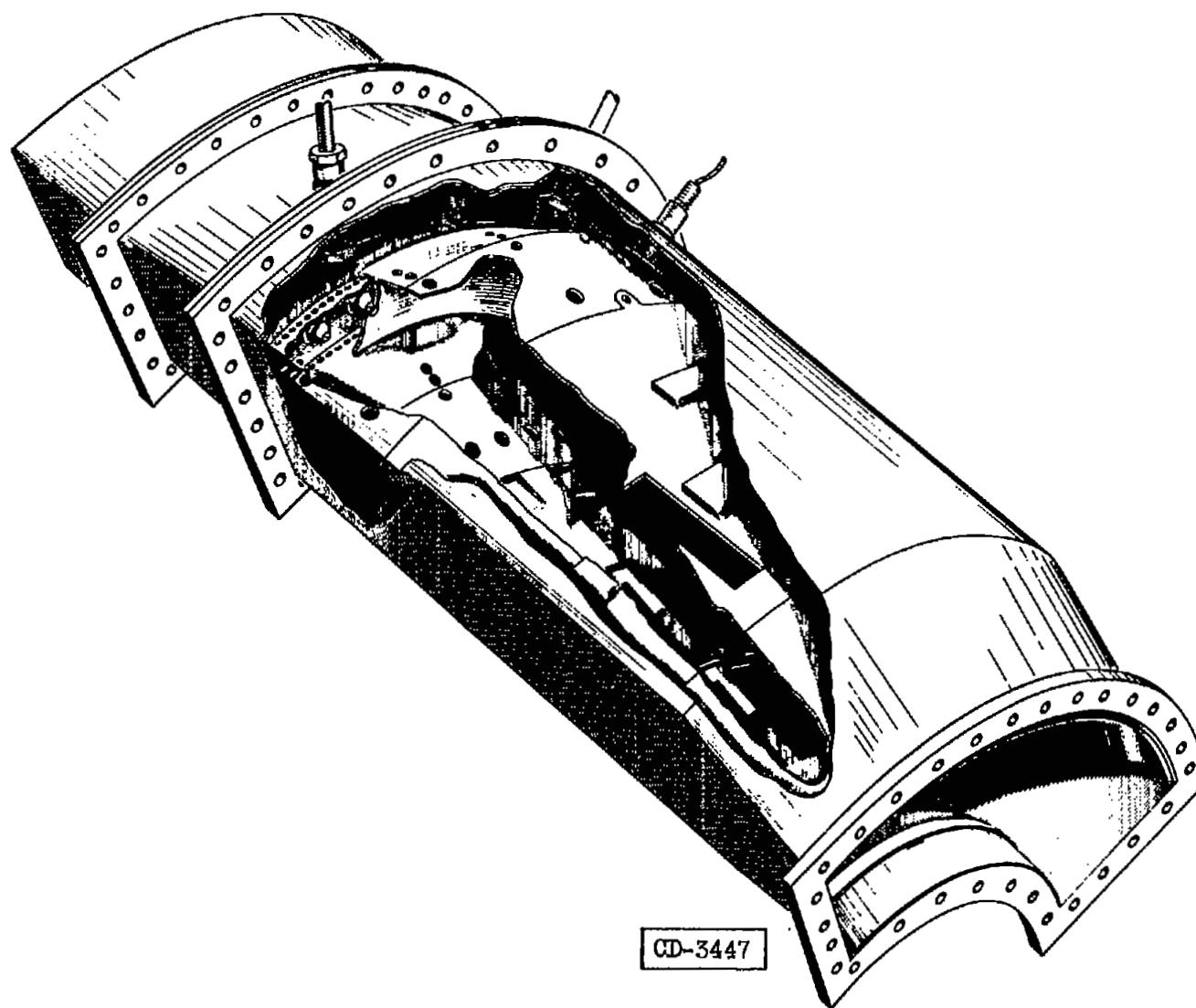
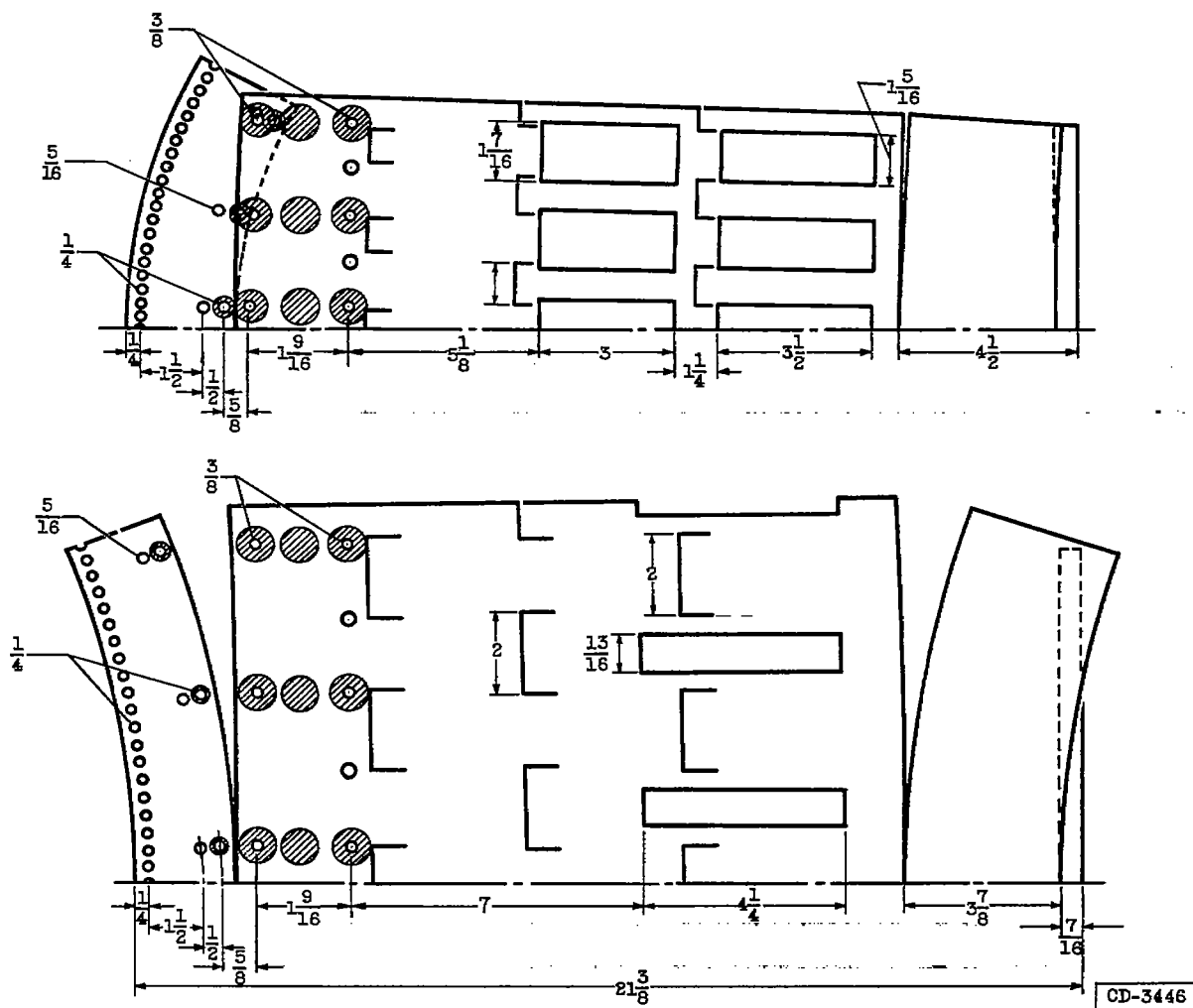


Figure 4. - One-quarter sector of annular combustor assembled in test ducting.



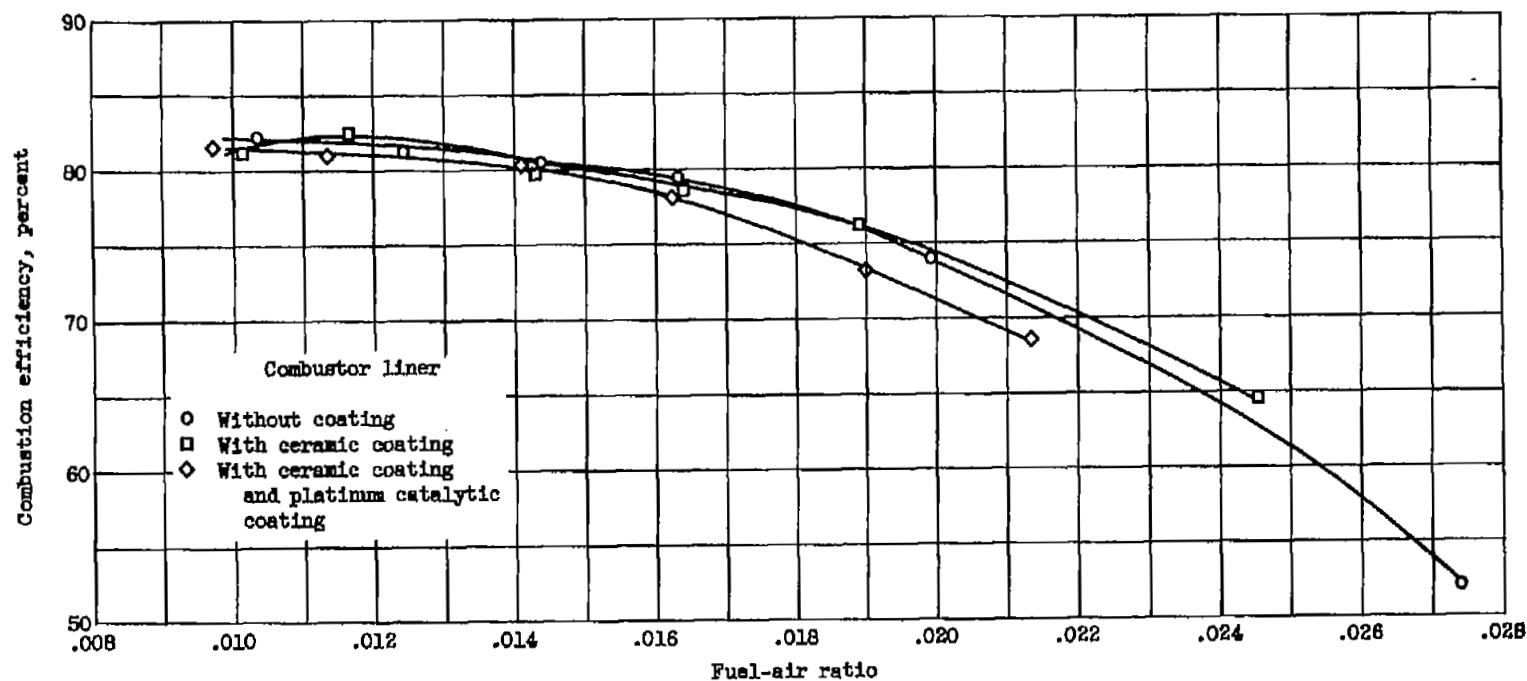


Figure 8. - Effect of internal-liner coatings on combustion efficiency. Combustor-inlet pressure, 5 inches mercury absolute; combustor-inlet temperature, 268° F; air flow, 0.714 pound per second per square foot.

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